Indian J. Phys. **70A** (1), 139–144 (1996)

IJP A
— an international journal

Investigation of (^{12}C, ^{11}B) reaction on ^{88}Sr

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Abstract : Angular distributions of ^{11}B observed in transitions to low-lying states of ^{89}Y in the reaction ^{88}Sr (^{12}C, ^{11}B) have been measured at an incident carbon energy of 87.5 MeV. The angular distribution of the elastic scattering cross section measured simultaneously has been fitted to obtain the optical potential in the entrance channel. The measured one proton transfer data has been analysed using the finite range DWBA theory and a normalisation constant has been determined for the transitions studied here.

Keywords : Multi-nucleon transfer reaction, finite range DWBA theory

PACS Nos. : 25.40 Hs, 24.10.Eq

1. Introduction

A study of single- and multi-nucleon transfer reactions induced by ^{12}C projectiles on ^{88}Sr at incident energies above the Coulomb barrier has been taken up to understand the reaction mechanism. In the present communication the results of the one proton stripping reaction, namely ^{88}Sr (^{12}C, ^{11}B) ^{89}Y are reported.

2. Experimental details and results

Incident ^{12}C ions of 87.5 MeV energy from the Bombay Pelletron accelerator were bombarded on a natural SrO_2 target 50 microgram/cm^2 thick evaporated on carbon backing mounted at the centre of a 1 m-diam scattering chamber. Reaction products were detected and identified by two surface barrier detector telescopes each consisting of a E (30 micron) and E (300 micron) detectors. An energy resolution of 500 KeV was obtained for the elastic group. Well known particle identification algorithm was used to identify the reaction products. A typical particle identification spectrum is shown in Figure 1 and shows good mass seperation. Here the C group has been excluded for the sake of clarity. Since the isotope $A = 88$ forms 82% of the natural Sr, contributions due to other components are assumed to be negligibly small. Figure 2 shows total energy spectrum of ^{11}B obtained by

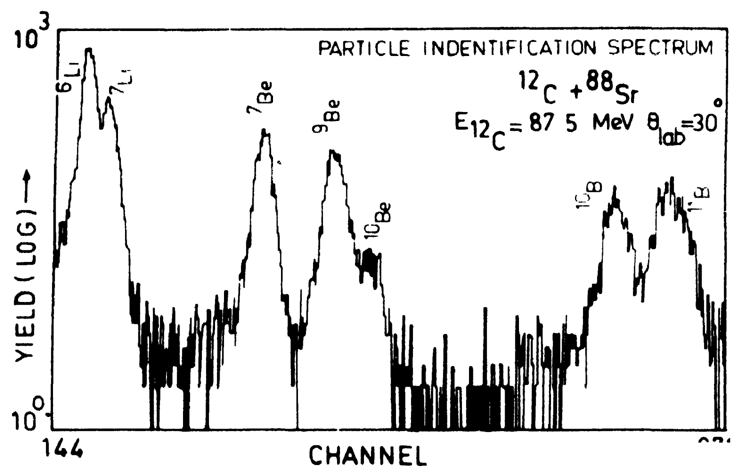

Figure 1. Particle identification spectrum in ^{nat}Sr (^{12}C, X) at $E_{inc} = 87.5$ MeV and $\theta_{LAB} = 30°$.

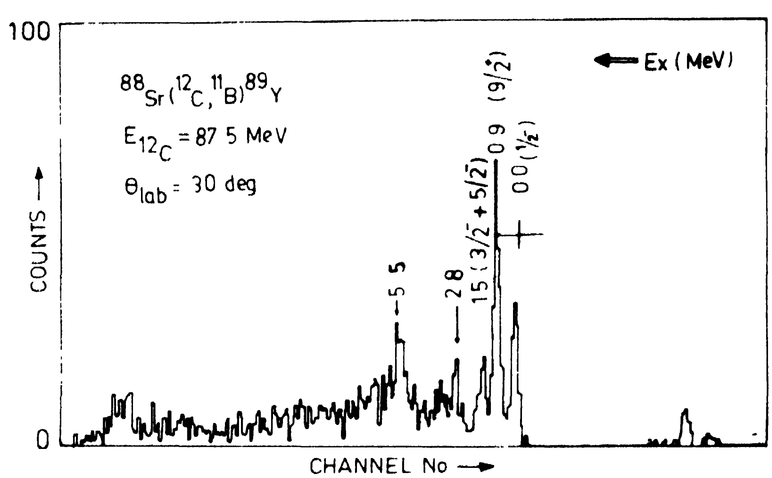

Figure 2. Boron spectrum in the reaction ^{88}Sr (^{12}C, ^{11}B) ^{89}Y at $E_{inc} = 87.5$ MeV, $\theta_{LAB} = 30°$.

putting appropriate gate on ^{11}B. Transitions to the states corresponding to ground state ($1/2^-$) and $Ex = 0.9$ MeV ($9/2^+$) in ^{89}Y can be identified. The states at 1.49 MeV ($3/2^-$) and at 1.74 MeV ($5/2^-$) in ^{89}Y could not be resolved and is seen as a somewhat broad structure in the spectrum at 1.5 MeV excitation energy. The broad hump at around 5.5 MeV excitation may be due to the Q–opt consideration.

3. Analysis and discussion

Angular distributions of the first three transitions have been measured in the angular range 12°< <30° and analysed using a finite range DWBA code LOLA [1]. The optical model parameters (Table 1) were obtained by fitting the angular distribution of elastic scattering cross sections for the system ^{12}C + ^{88}Sr which are also measured in the present study using

Table 1. Optical potential for ^{12}C + ^{88}Sr at 87.5 MeV.

V (MeV)	r_0(fm)	a_0(fm)	W (MeV)	r_i(fm)	$a_i$fm)	r_{oc} (fm)
248.3	0 871	0 692	247 39	0 807	0 669	1.3

the optical model search code [2] SNOOPYBQ (Figure 3). For the bound state wave functions calculations the proton before and after the transfer was assumed to be bound in a

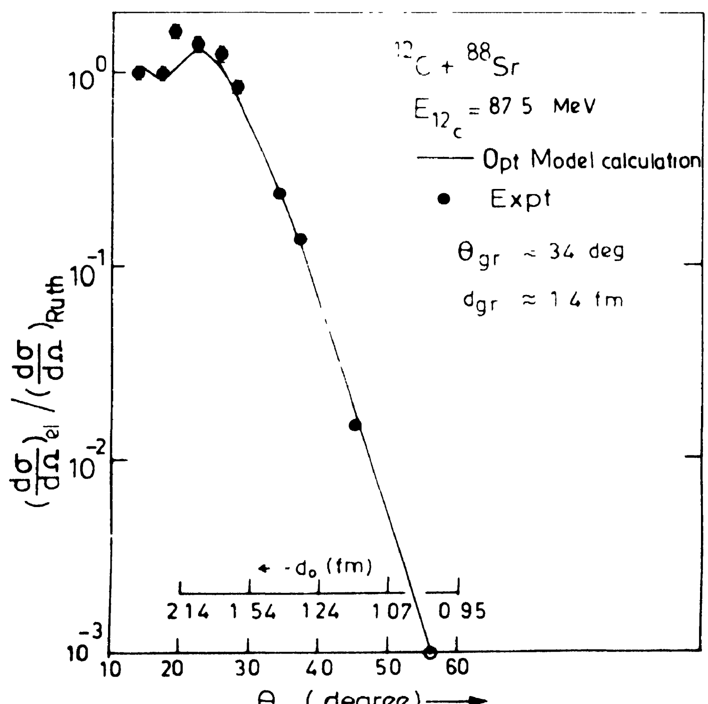

Figure 3. The differential elastic scattering cross section normalised to the Rutherford cross section for ^{12}C + ^{nat}Sr at 87.5 MeV. The solid line is the optical model calculation.

Wood-Saxon well with the parameters r_0 = 1.25 fm and a_0 = 0.65 fm. The depth of the well was adjusted to reproduce the known seperation energy of proton in ^{12}C and ^{89}Y.

The results of finite range DWBA calculations along with the experimental points for the g.s., the 0.9 MeV state and the states at 1.5 MeV in ^{89}Y are shown in Figures 4, 5

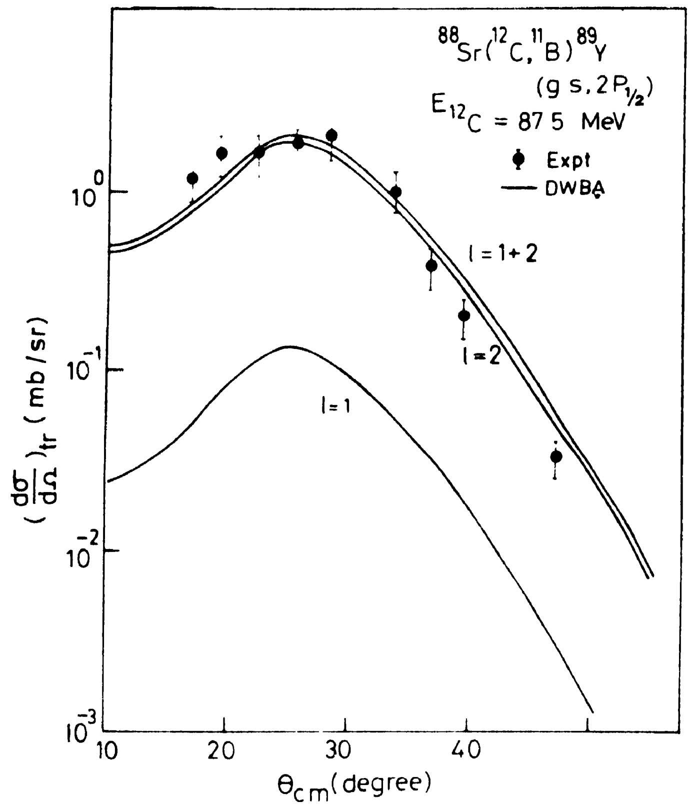

Figure 4. Angular distribution of cross section of ^{11}B in transition to the g.s of ^{89}Y along with the finite range DWBA calculation .

and 6 respectively. The measured cross section is related to the calculated cross section through the relation

$$\left.\frac{d\sigma}{d\Omega}\right)_{\rm Expt} = N_0 \frac{(2J_B+1)}{(2J_A+1)} C^2S_a\ C^2S_b \left[\frac{d\sigma}{d\Omega}\right]_{\rm LOLA}$$

where the notations have their usual meaning. The theoretically calculated cross section $(d\delta/d\Omega)_{\rm LOLA}$ in the incoherent sum of cross sections due to all possible l-transfer values subject to the selection rules

$$j_a - j_B < l_{tr} < j_a + j_B.$$

$$l_a - l_B < l_{tr} < l_a + l_B.$$

In the present study the selection rules permit $l_{tr} = 1$ and 2 for the g.s. and $l_{tr} = 3, 4, 5$ for the 0.9 MeV state. Similarly for the two states at E_x = 1.5 MeV, namely $l_{tr} = 0, 1, 2$ for $3/2^-$

state and l_{tr} = 2, 3, 4 for $5/2^-$ state are allowed. The resulting angular distribution of the incoherently added cross sections for different l_{tr} values is shown as "fits" to the measured

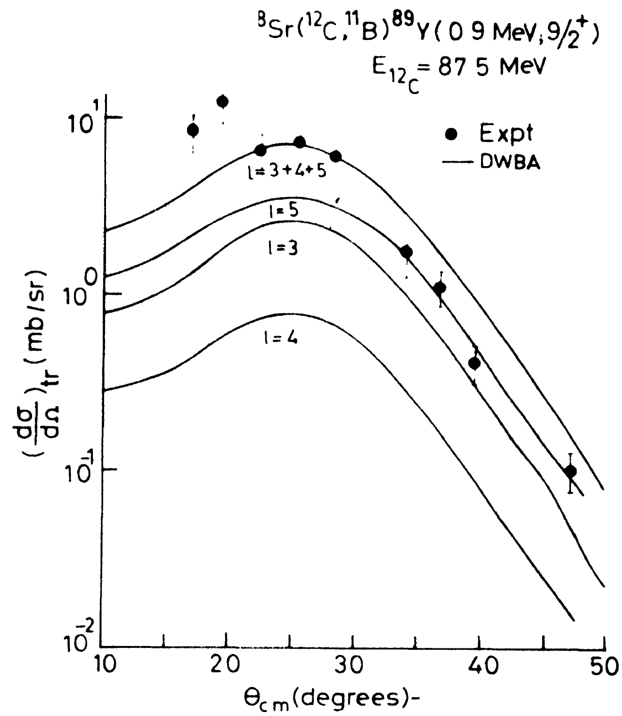

Figure 5. As in Figure 4; for the 0 9 MeV state in ^{89}Y

angular distributions in Figures 4, 5 and 6. The DWBA results, in all the cases, show a reasonable agreement in predicting the shape and peak position of the measured angular distributions.

The spectroscopic factor C^2S_B for the proton stripping from ^{12}C is taken as 2.85 from the shell model calculations [3]. The values of C^2S_B for describing the overlap $|\langle ^{88}Sr + p|^{89}Y\rangle|^2$ have been taken from the ^{88}Sr (^3He, d) studies of Vourvopoulos *et al* [4]. The values of the normalisation constant N_0 obtained in the present study for various transitions are listed in Table 2. An average value of N_0 = 0.0133 is obtained from the present investigations.

Variation of the bound state parameters and their effect on the magnitude of the cross section were investigated. For the light system ^{11}B + p, standard choice of r_0 = 1.25 fm and a_0 = 0.65 fm was adapted while for the ^{88}Sr + p system both the bound state parameters namely, r_0 and a_0 were varied. It is observed that the effect of a_0 variation is not large while r_0 variation between 1.15 fm to 1.35 fm leads to a variation in cross section differing by a factor 2. It is well known that the magnitude of cross section and hence the value of N_0 is sensitive to the choice of various bound state parameters. However, a reasonably consistant value of N_0 for the observed transitions suggests that the interaction

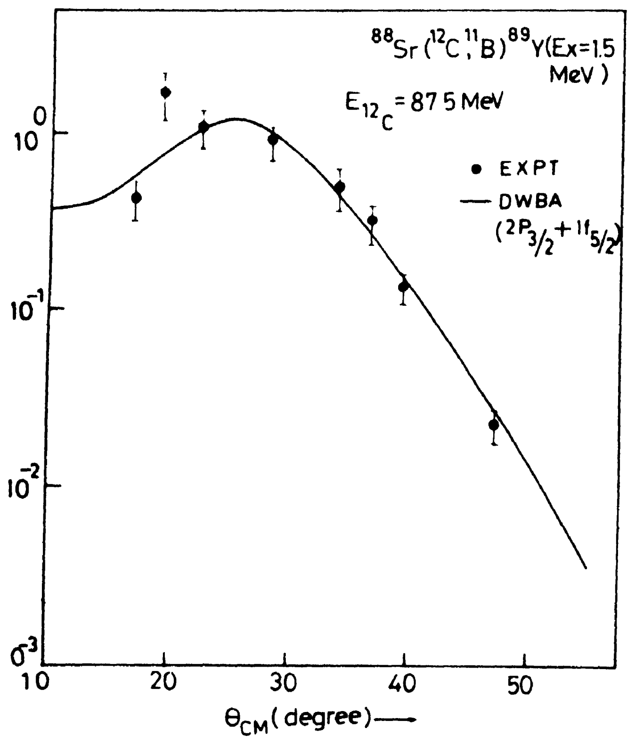

Figure 6. As in Figure 4, for the E_x = 1.5 MeV state in ^{89}Y.

Table 2. Normalisation constant (N_0) for the reaction ^{88}Sr (^{12}C, ^{11}B) ^{89}Y.

Exc. energy (E_x)	N_0	$(N_0)_{average}$
0.0 MeV	0.0135	
0.9 MeV	0.0178	0.0133
1.5 MeV	0.0087	

responsible for single proton transfer in the present reaction is "direct" type and can be described in terms of DWBA theory.

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